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PARTICULARS OF SURFACE QUALITY CONTROL WITH MECHANICAL WORKING OF GLASS CERAMIC ARTICLES

V. A. Rogov,[1] E. I. Suzdal'tsev,[2] and M. I. Shkarupa[2]

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The results of investigations of diamond polishing of glass ceramic are presented. A technological system of diamond flat polishing of articles made of brittle nonmetallic materials is obtained. The factors characterizing the technological system before mechanical working are described. The proposed technological scheme will make it possible to model the mechanical working of glass ceramic articles more efficiently.

Key words: diamond polishing, glass ceramic, surface layer, inter- and in-crystal strain, stress relaxation, surface quality control.

The fabrication of construction-ceramic articles must be based on a gradual decrease of the defects produced by working in order to provide strength to the articles and ensure their operational reliability. The structure and properties of the blank materials determine the choice of the tooling and the working schemes and regimes. Intensification of the grinding regime, first and foremost, an increase of the cutting force, results in the development of defects in the surface layer of the articles and, in consequence, the surface characteristics are degraded. Changing the regime parameters permits controlling the damage to the worked surface of technical sitals and ceramics while giving the strength prescribed for the article. The damage arising during working should not exceed the level of structure defectiveness. In this case the strength of the ceramic articles does not decrease.

The process of fabricating articles from construction ceramic or technical glass, just as any technological system, can be represented as a set of elements which are linked with one another and forming a unified whole. Together with the choice of materials, which presupposes the choice of a system of physical – mechanical properties, it is necessary to obtain the required indicators for the surface layer of the articles, which are formed successively in a series of steps [1].

To determined the structure and interrelations of the indicators and the factors of the process, the limitation of the main parameters, and the ranges of variation of the factors controlling the variables we shall examine a technological system of diamond grinding as a controllable object with inputs and outputs. We shall separate the input variables of the diamond grinding process which characterize the technological system before mechanical working (Fig. 1).

The first group of factors that characterizes the technological system before working includes the parameters of the cutting tool [2]. We shall describe them by means of the following sequence of terms

$$\mathrm{I} = x_1 = [\mathrm{GR}, C, P_c, G_c^b],$$

where GR is the graininess of the diamond wheel, ìm; C is the relative concentration of the diamond grains, %; P_c is the static strength of the diamond powder under compression (GOST 9206–80), N; and, G_c^b is the ultimate strength the binder under compression, MPa.

The second group of input variables of the process that characterizes the blank to be work is:

$$\mathrm{D} = x_2 = [T, G_f],$$

where T is the thickness of the worked plate, μm, and G_f is the fracture strength of the material of the article, MPa.

The third group comprises technological parameters. It is assumed that the technological conditions of working and the composition and feed method of lubricating – washing liquid remain unchanged.

The grinding regimes comprise the fourth group. We shall write the following variables, by means of which different values for the capacity of the process can be obtained directly, in order:

$$\mathrm{C} = [v_w, v_{tb}, S, t],$$

where v_w is the speed of the diamond wheel, m/sec; v_{tb} is the speed of the table, m/min; S is the transverse feed, mm/pass; and, t is the depth of grinding, mm.

[1] Russian University of Friendship Among Peoples, Moscow, Russia (E-mail: tatrg@yandex.ru).
[2] Federal State Unified Enterprise Obninsk Scientific and Industrial Enterprise "Tekhnologiya," Obninsk, Moscow Oblast', Russia.

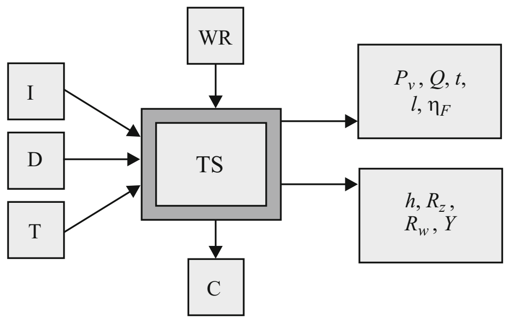

Fig. 1. Technological system (TS) of diamond flat grinding of articles made of brittle nonmetallic materials. *Input parameters* (factors): I) parameters of the cutting tool (diamond wheel); D) parameters of the article being worked; WR) work regime; T) technological parameters of the grinding process. *Output parameters of the process*: C) volume capacity of the grinding process, mm^3/min; P_v) cutting force, N; Q) diamond consumption, mg/mm^3; t) temperature of the cutting zone, °C; l) stability of the wheel between truings, mm^3; η_F) relative effective contact cutting surface, %. *Output parameters of the article*: h) depth of damaged layer, μm; R_z) height of the nonuniformities of the profile, μm; R_w) waviness of the surface, μm; Y) article surface quality parameter (roughness), μm.

The main objective of the mechanical working of articles is to impart a prescribed geometric shape and dimensions and obtain the optimal technological quality of the surface layer. The term "surface quality" means a collection of properties of the surface layer of the material being worked (roughness, dislocation density, structure defectiveness, and other characteristics). These properties determine the operational, specifically, antifriction, properties and longevity of the components of the rubbing parts.

Diamond grinding is the most effective method of removing stock in ceramic blanks as a result of their high hardness. The finish dimensions of the stock are determined by the need to remove the defective layer appearing at the preceding step and by the need to come as close as possible to the exact geometric shape. Because of the defects in the surface layer damage quickly accumulates and develops in the material of the article during operation, resulting in the appearance of cracks in and fracture of the article [3].

The systems approach to the analysis of surface formation by grinding makes it possible to find the correct way to choose the conditions under which the required surface quality parameters are obtained for an article. The task of the grinding system is to remove stock while imparting the prescribed geometric shape and dimensions as well as to form the optimal technological quality of the surface layer. The physical and chemical processes and phenomena arising between the cutting elements of the tool and the worked surface play a large role in the determining the operating properties of the article; these processes determine the interaction force acting between grains of the wheel and the stock being removed. The cutting force on a grain depends on the physical – mechanical properties and cut section of the material along the grain. In turn, the distribution of the stock over the cutting zone also determines the distribution of the cutting forces over it. For this reason, it is impossible to study the laws of formation of the surface layer of ceramic articles without investigating the kinematics of the interaction of the tool and the blank and the probabilistic character of the contact of the diamond grains and the stock material [4].

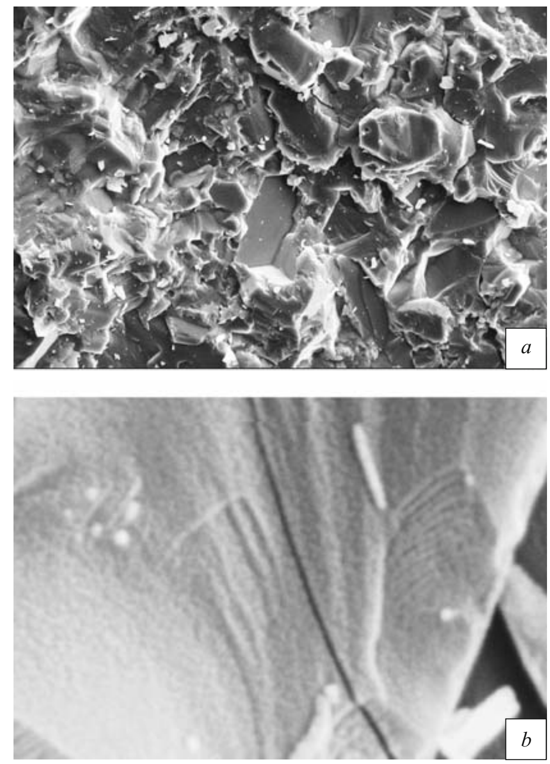

Fig. 2. Microstructure (a, × 1000) and nanostructure (b, × 50,000) of the polished ceramic samples of silicon carbide with surface quality index R_a = 0.2 μm.

The mechanism by which a surface layer forms in ceramic is different from the process occurring during diamond grinding of metals. Elastoplastic deformation without fracture, dispersal of the stock during plastic deformation, and brittle fracture with spalling of particles occur during grinding of brittle nonmetallic materials [5]. The probability of a particular mechanism of fracture of the stock is determined by the physical – mechanical properties of the material and the load on a grain (work regimes). Figure 2*a* (EVO 40 Zeiss scanning electron microscope) clearly shows the direction of the working and tracks left by the grains during fracture of the stock. An examination of the surface showed that under the action of a diamond grain the material being worked manifests elastoplastic properties. Plastic flow of the material together with shear deformations can be seen in Fig. 2*b*. Therefore, the maximum tangential stresses reach a critical value immediately below a grain. As a result of the difficulty of plastic deformation arising, the process of relaxation of the stresses at crack tips present in the ceramic proceeds poorly. This gives rise to brittle fracture. Together with

intracrystalline deformation, intercrystalline deformation — relative slip and rotation of grains, fragmentation of individual grain blocks, and fracture of the grain boundaries and grain blocks — also occurs during working of ceramic.

The mechanism of grinding of glass ceramic consists in the interaction of physical (friction) and chemical (reactions) processes, i.e., grinding of glass ceramic is a tribo-chemical process. Determining the mechanism of grinding is a classic problem of friction and wear. When grinding is done with 1 – 0.25 μm abrasive grains only the mechanism of removal of material on a molecular scale operates. Quite a large amount of energy is required. The effect of the tribo-chemical action on the glass ceramic corrosion-active component introduced into the polymer binder of the grinding wheel is considerable. As investigations have shown, grinding wheels with NH_4Cl give a 1.5 – 9 times larger capacity than wheels with no activator with larger (by a factor of 6) power consumption and lower (by a factor of 2.5) durability. When using with wheels without an activator under the same conditions, the surface remains not ground but matte. The probability of NH_4Cl interacting with the hydrates of silicic acids, formed on the surface of the glass ceramic as a result of hydrothermal reactions, and manifestations of an ion exchange reaction has been determined by means of IR spectroscopy.

In summary, as a result of the combined action of a substantial specific pressure at the location of the contact of the article and the grinding wheel, the heat generated by friction, and the presence of water, the surface layer of the glass ceramic can be become disorganized in a layer different from the bulk, followed by removal of the layer by the grinding wheel. Ultimately, the process of grinding glass ceramic by a tool with secured grains of an abrasive consists of combined working based on tribo-chemical action of a corrosion-active component present in a composition consisting of the binder of the grinding wheel and the glass ceramic being worked at a definite level of power consumption and heat.

It has been established that the effectiveness of the surface quality control during mechanical working of a glass ceramic is comprised of several factors:

increase of the capacity of working;

rationalization of the technological processes involved in working articles;

control of the quality of the surface layer — roughness and defectiveness of the surface;

economic parameters, such as labor- intensiveness and cost of working;

improvement of the tooling, technological fittings, attachments, and equipment;

physical – chemical properties of the material of the blank being worked; and,

tool wear.

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